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ABSTRACT

This paper outlines the imbalance in Australia's intellectual and high technology trade, and argues that if Australia is to move beyond being a high technology colony, a new attitude toward research and development needs to be engendered, particularly in the private sector of industry. It is noted that Australia supplies a small number of the world's patents, imports much of the high technology and technical expertise used in her industries, and has a high concentration of foreign owned manufacturing. It is suggested that one solution to this scarcity of home grown technology, which would involve closer collaboration between higher education and industry, is a scheme along the lines of the Total Technology Ph.D. program now in effect in the United Kingdom. Four tables present data on the number of patents granted in selected countries in 1980; balance of trade in technology--comparison for various countries in 1981; payments and receipts by private enterprise for technical know-how in Australia, 1976-77 and 1978-79; and foreign ownership, research intensity, and technology purchase in Australia's manufacturing industry. (15 bibliographic reference notes) (Author/EW)

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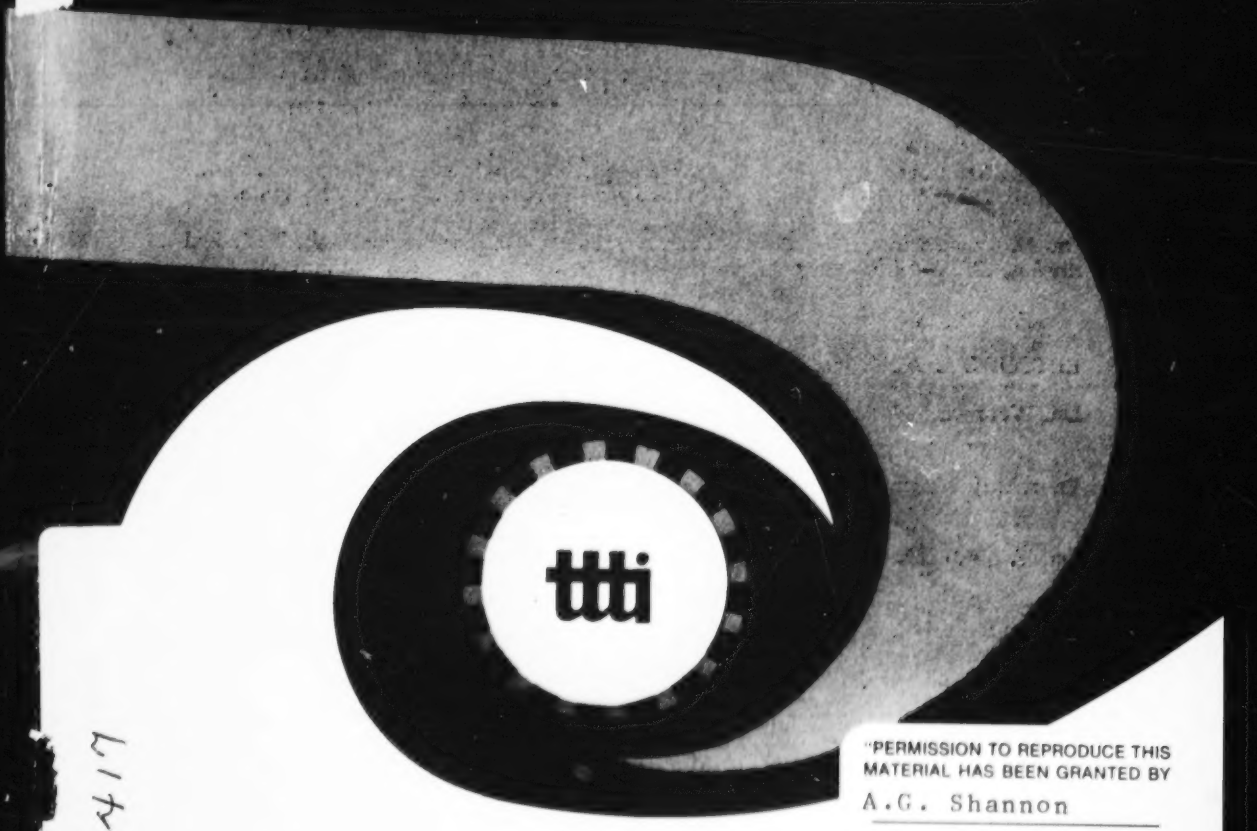

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High Technology in Australia: Rhetoric or Reality?

J. G. Sekhon and A. G. Shannon

ABSTRACT

This paper outlines the imbalance in Australia's intellectual trade with particular reference to patents. It is argued that if Australia is not to remain a high technology colony, then a new attitude to research and development needs to be engendered, particularly in the private sector of industry. One solution, which would involve closer collaboration between higher education and industry, is a scheme along the lines of the Total Technology Ph. D. Programme in the United Kingdom.

Introduction

There is much talk about high technology in Australia. We hear about it from business leaders, editorial writers, academics and a few politicians. There is even a little action evident, with efforts to establish some industrial parks and with isolated initiatives from a few, very few, companies.

What we do not hear much about is where the human resources are going to come from to fulfil these great expectations. We comment here on some aspects of the human infrastructure needed to sustain the dreams.

We are not saying that this sudden surge of interest in high technology is not to be applauded; rather we are claiming that a radical reappraisal of ends and a redirection of means are needed. We illustrate this by reference to Australia's record in intellectual trade.

The draft report prepared by the Committee of the Australian Scientific Industry Association[1], whose membership includes representatives from universities, government and industry, articulates its concern in these words:

> Australia's overall research and development expenditure is too small, her priorities are askew, and the innovative capabilities of small high-technology companies are not being nurtured. . .Australians still have a 'cargo cult' mentality about technology, regarding it as something that is imported and grafted to their needs. . Unless there are significant changes in attitudes and activities in Australia, our standard of living will fall inexorably as the years go by.

The data presented in this paper are a manifestation of the low level of indigenous industrial R and D activity. When to this is added the fact that Australia's gross expenditure on R and D as a proportion of her GDP is dismayingly low, the dimensions of her dependence on foreign technology become patently plain.

It bears mentioning that on the basis of two indices — technology-intensive exports per capita and the ratio of exports over imports in high technology products — only Greece was lower than Australia among the 24 OECD countries (Jones[2]). The question is whether we can reorder our industrial priorities and change our R and D habits quickly enough.

Patents

Australia has a distinguished record of basic research, but most of the fruits of research have been sold cheaply to foreign organisations and the products brought back later at high cost. Moyal[3] maintains that Australia now generates 2 per cent of the world's scientific research, but only 0.7 per cent of patents.

There are two principal reasons as to why Australia supplies less than 1 per cent of the world's technology in terms of patent property:

- the low proportion of national R and D performed by, and in, the private sector; and
- the pure science bias and inadequate patent orientation of much of the public sector R and D.

The Interscan (Australian Microwave Landing System) is Australia's most ambitious and daring bid yet to win high technology export markets worth hundreds of millions of dollars. The Interscan *is* a major triumph and breakthrough for innovative research. However, Interscan *as a concept*, albeit a brilliant concept, cannot be patented. It is the supply of hardware — the antennae and associated instrumentation with which airports must be equipped — that is the money spinner.

The primary need is to translate our ideas more vigorously into successful commercial ventures. Thornton[4] *et al* ruefully reflect:

> In the CSIRO, University and CAE laboratories, the computers are more likely to be Control Data or IBM or ICL. Yet, CSIRO and the University of Sydney played a pioneering role in computer design. The Government departments and instrumentalities as well as institutions of higher education place orders for computers outside Australia.

Patents have been widely canvassed and used as a measure of innovative activity. The extent of dependence on overseas sources for new manufacturing technology can be measured by patent statistics.

Though inter-industry or inter-country differences in patent activities must needs be interpreted with caution, international differences in the proportion of patents issued to residents and foreigners provide a useful indicator of inventive output and national success in generating domestic technology. Table 1 shows the number of patents granted in selected countries. The table confirms that a higher proportion of patents granted by the Australian Patent Office in 1980 were to foreign applicants. Among the countries shown in the table, only Canada recorded a higher proportion of patents issued to foreigners. However, the Canadian figure evidently reflects the geographical proximity to the United States. Further, the data shown in Table 1 are even more remarkable: they are independent of country size. It is evident that Sweden and Switzerland, with smaller populations than Australia, appear to depend less heavily on foreign technology. To put more affirmatively, it can be asserted that Sweden and Switzerland have been more successful than Australia in generating new manufacturing innovations.

The clear finding which emerges from Table 1 is the exceptionally low level of Australian patenting activity by international standards. Of the countries in the minor proportion of local patenting category, only Canada is lesser than Australia.

TABLE 1: Number of patents granted in selected countries, 1980.

Country	*Patents granted to*		*Percentage granted to non-residents*
	Residents	*Non-residents*	
Australia	620	7,805	93
Belgium	837	5,081	86
Canada	1,503	22,392	94
France	8,438	19,622	70
F. R. of Germany ..	9,826	10,362	51
Japan	38,032	8,074	18
Netherlands	417	2,907	87
Sweden	1,394	3,604	72
Switzerland	1,475	4,486	75
United Kingdom ..	5,158	18,646	78
United States	37,152	24,675	40

Source: Gannicott[5]

Technological balance of payments

Though Australia is regarded as an industrialised nation, it has long been a cliche that she has been content to import technology and technological skills. Her dependence is most marked in the manufacturing sector and her trade is characterised by a considerable imbalance in high research-intensive imports and exports.

The adequacy and scale of domestic research and development may be inferred from available data on the inflow of foreign technology. Table 2 shows that Australia is a heavy net importer of technology, having one of the worst export/import ratios. Anyone would expect Australia to be a net importer of know-how, which she is; but the data show that in comparison with other major OECD countries, she is an *unusually* heavy importer. It is noteworthy to observe that of the countries listed in Table 2, only the US and the UK indicate a *surplus* on their balance of trade, countries which allocate a relatively high proportion of their gross domestic product (GDP) to research and development expenditure.

Further evidence of Australia's imbalance in high technology trade is provided by the ABS (Australian Bureau of Statistics) surveys of research and experimental development undertaken by the private sector. These data, summarised in Table 3, are generally superior, as their coverage is broader and therefore more comprehensive.

TABLE 2: Balance of trade in technology: comparison for various countries 1981

Country	(1) *Exports* ($ m)	(2) *Imports* ($ m)	(3) (1) ÷ (2)
United States	6,170	600	10.3
United Kingdom ..	968	750	1.3
Italy	724	1,043	0.7
F. R. of Germany ..	460	1,000	0.5
France	419	802	0.5
Japan	410	1,450	0.3
Australia	22	126	0.2

Source: Morris[6]

TABLE 3: Payments and receipts by private enterprises for technical know-how, Australia: 1976-77 and 1978-79 ($ m current prices)

Industry	(1) *Receipts for technical know-how from overseas*		(2) *Payments for technical know-how made overseas*		(3) (1) ÷ (2) %	
	1976-77	1978-79	1976-77	1978-79	1976-77	1978-79
Manufacturing	6.0	7.8	51.9	78.0	11.6	10.0
Mining and other industries	1.1	3.8	13.2	50.1	8.3	7.6
Total all industries (excluding agriculture, forestry, fishing and hunting).	7.1	11.6	65.1	128.2	10.9	9.1

Source: Morris[6]

As can be seen from Table 3, Australia has a large and increasing deficit on its overseas balance of payments due to royalties and copyrights. In 1978-79, payments exceeded receipts by $ 116.6 m, compared with $58 m in 1976-77. To quote Morris[6],

> At constant 1976-77 prices, the 1978-79 balance (the difference between receipts and payments) was – $ 98.4 m, which represents a deterioration over 1976-77 of about 70 per cent.

Indeed, as the Federal Minister for Science and Technology (Jones[7]) affirms, Australia ran in 1980 a trade deficit of some A$6 million in goods with a high research content.

Foreign-owned Companies

Aside from a concern with the repatriation of profits, the performance of the host country may be seriously impaired as a result of entry of multinational enterprises. The availability of imported technology acts as a brake on domestic innovation. This is all the more serious as foreign firms are generally concentrated at the innovative, high-technology end of the market.

The extent of foreign ownership, research intensity and technology purchase intensity within the manufacturing industry is given in Table 4.

TABLE 4: Foreign ownership, research intensity and technology purchase in manufacturing industry.

Manufacturing Industry	*Foreign Ownership (percentage)*	*R & D Intensity*	*Technology Purchase Intensity*
High Technology			
Pharmaceuticals	63	High	High
Chemicals	63	H	H
Electrical Machinery ..	39	H	H
Other Machinery ..	39	H	H
Medium Technology			
Glass, Clay	18	Medium	H
Fabricated Metal Products ..	16	M	M
Transport Equipment ..	66	M	M
Low Technology			
Textiles, Footware ..	20	Low	M
Wood Products	8	L	L
Basic Metal Products ..	37	L	L
Food, Beverages and Tobacco	26	L	L

Source: Manderville, Lamberton and Bishop[7].

The table shows that foreign ownership is most pronounced in such capital-intensive, high technology industries as pharmaceuticals, chemicals and petroleum, and electrical machinery. The foreign ownership percentages doubtless understate the present position, as foreign control as a whole has increased in Australian manufacturing industry in the recent past. Hence, there is heightened concern that Australia may become a technological colony. Furthermore, R and D intensity is high in the high technology industries which are to a large extent under foreign control.

There is growing support for the view that increasing foreign ownership and control of Australian industries run counter to the national interest. Foreign technology is rarely suited to Australian conditions, raw materials and scale of production. The domestic activity is largely confined to adaptation. However, the disadvantages do not end there. As Johnston[8] has observed:

> It can be concluded that not only has the reliance of Australia on foreign technology increased, but the growing control of technology by TNCs (transnational corporations) and the restricted basis on which these companies are able to make it available for transfer, suggests that Australian manufacturing industry is effectively being excluded from the new and important technologies except on a 'captive consumer' basis.
>
> Thus there is very good evidence that Australian industry is becoming increasingly reliant on foreign technology and that this technology is introduced into Australia under terms of strict control by the foreign manufacturers. Indeed there is evidence that in key technologies, Australia is systematically denied access. The level of technological expertise has fallen so low in manufacturing industry that firms no longer have the capability to evaluate and select foreign technology.

The evidence mustered by Jones[9] highlights characteristics of R and D in Australia, namely the low level of overall spending by international standards; and the predominance of the government sector as both source of funds and performer of research.

From these two features flow two further facets of R and D in Australia, namely the high proportion of basic research rather than applied research and experimental development; and, the low level of spending on industrial R and D. In fact, the total investment by the private sector in R and D is extremely small; when measured as a percentage of GDP, we have one of the lowest rates of private sector R and D funding among OECD countries. This meagre commitment to R and D by private industry is an aspect of our dependence and an index of our vulnerability which bears careful consideration when we are planning where and by whom the national research and development effort will be carried out.

Solutions: Three British Initiatives

Having outlined some problems, can we offer some solutions? There is no universal panacea, of course, and we feel that our most important contribution to the debate is to highlight the problem. We delineate three British initiatives which, in our view, deserve serious consideration by universities and other institutions of higher education.

The Percy[10] Committee was emphatic that deficiencies in British industry were rooted in education. It said:

> The evidence submitted to us concurs in the general view: first, that the position of Great Britain as a leading industrial nation is being endangered by a failure to secure the fullest possible application of science to industry; and second, that this failure is partly due to deficiencies in education.

The Jones[11] Committee, no less certain

of the value of education and training, advised that universities should reverse the current tendency to train scientists towards academic achievement as an end in itself, and should direct the emphasis of their education more towards the needs of manufacturing industry. It went on to say:

> ..students are encouraged to believe that academic achievement is an end in itself and that continuing academic research is the only respectable outcome of their training ..whenever (this attitude) exists it reflects a total unawareness of the realities of the present national situation .. we must look for the solution here in a change of emphasis .. towards the needs of industry. In particular, research work in industrial laboratories should be far more readily recognised for higher degrees. We consider that if scientists were brought up to believe, and trained in curricula which recognised that manufacturing industry is an honourable occupation on which depend the economic strength and prosperity of the community, more would choose to enter it as a career.

There have been a number of valuable attempts in British universities and in polytechnics under the Council for National Academic Awards (CNAA), to move the balance and relevance of Ph.D. education. The tremendous changes brought in the Ph.D. programmes in the universities in Britain relate to shortage of scientists who can apply the results of research to development. The feeling is growing that the traditional straight doctorate, based solely upon full-time research activity in residence leading to the doctoral dissertation, constitutes undue specialisation. There are growing doubts about the value of many theses and about the training that this exercise provides. The Science Research Council is withdrawing support for pure research and giving, more and more, for research that has potential applications or is otherwise related to industry. Part-time doctoral research is being permitted and scientists employed in government or industrial research establishments are being increasingly permitted to submit their experimental results to a supervising university to be considered for acceptance in satisfaction of Ph.D. requirements. As Bragg[12] puts it:

> ..the Ph.D degree, with its emphasis on individual work, often in a narrow specialist field, was seen by many employers as a 'training in unemployability'. The first real attempt to change this situation was the introduction of the scheme now known as CASE — Cooperative Awards in Science and Engineering. Under this scheme the project for a Ph. D. is chosen by an industrial company, in collaboration with an academic department .. after a slow start this scheme has proved very popular. About one third of the 2000 new awards to students for Ph.Ds are now CASE. They are ideal for investigating problems which a company can deal with empirically for the time being, and which it cannot spare a man to work on immediately, but which it feels could become important in the long term. Some large companies keep a 'portfolio' of CASE projects, using them as their method of recruiting Ph.Ds. They are spin-off benefits in promoting regular contacts between an academic department and the company.

(a) *Aston University Approach*

At Aston University, Birmingham, and at two other technological universities, the "sandwich" principle is being applied at the Ph.D. level with post-graduate students alternating study on campus with research in an industrial laboratory. The Interdisciplinary Higher Degree (IHD) Scheme at Aston was set up with the object of broadening post-graduate education and orientating it towards the needs of industry. The research projects are supervised by a team consisting of two members of the University staff from different depart-

ments and — most important — a member of the sponsoring organisation.

A major development has been the introduction of the 'Total Technology' to Ph.D. degrees which is sponsored by the Science Research Council. The total technology programme was designed as an alternate route to the doctoral award, a programme that would enable engineers to practise their professional specialism within the constraints imposed by the realities of industrial life. According to Husband[13]:

> There is no doubt that employers have found difficulty in making the best use of men trained to Ph.D. level in the conventional fashion... industry needs a certain quantity of very highly-trained engineers at the postgraduate level. But engineering skills are applied in industry within a framework of many functions including research, development, design, production, marketing and overall technological management. Thus, while there will always be a need for the orthodox approach to Ph.D. training in engineering there is likely to be a greater need for Ph.D. graduates with a good understanding of the wide range of functions involved in engineering and, more importantly, the knowledge and ability to integrate these functions in an effective fashion.

The problem of developing Ph.D. courses which would train graduate engineers in this much broader fashion was faced by a working party of the Science Research Council. The working party included representatives from higher education and industry. The term 'Total Technology' was put forward as an apt description of the new approach.

To quote from a Science Research Council leaflet on Total Technology

> Total Technology is a fresh approach to the Engineering Ph.D. It embraces the many functions of engineering — research, development, design, planning, production, operations, maintenance and marketing — and also the management skills needed to weld them into a successful whole. Total Technology aims to give young engineers a thorough training in all these functions to enable them to become effective, practical engineers quickly.

About ten universities and polytechnics offer Total Technology Ph.D. programmes as preparation for a successful career in industry.

A typical Total Technology student carries out a research project on an industrial problem in a firm under joint academic and industrial supervision; a group activity such as a design project: and attends lecture courses in related technical subjects and also in finance, economics, marketing and industrial relations and sociology.

The approach to the production of total technology Ph.D. graduates takes the form of a three-year programme of lectures, coursework and research.

(b) Loughborough Programme

The Loughborough Total Technology Ph. D. programme has been running since 1974. Collaborating companies include Plessey, Pye, RHP, Metal Box and Wilkinson Sword.

The normal procedure is for the student to enrol on the one year M.Sc. course in Manufacturing Systems Management and Development in the first instance. On successful completion of the M.Sc. examinations the student then moves to a sponsoring company to spend two years on field research.

The research topic involves the analysis and solution of a genuine manufacturing problem and the student is supervised by both University and company staff. It is also possible, however, for the student to complete the two year research segment within the University laboratories.

(*c*) *Oxford Study Groups Experiment*

The Oxford Study Groups with Industry is an eminently successful experiment in mathematical cooperation between the University of Oxford and industry. According to Ockendon[14], Tayler conceived the idea of applied mathematical Study Groups as a forum for bringing together Oxford applied mathematicians and industrial researchers whose problems were in some way connected with differential equations. The basic aim was to prevent physical applied mathematics in Oxford from becoming too unrelated to the real world and the idea was, and still is, to set aside five days for continuous intensive voluntary collaboration between the industrial visitors and faculty members and graduate students.

The spin-off from involvement with Oxford Study Groups with Industry in terms of graduate education in applied mathematics has been considerable. Students reading for higher degrees began to work on problems which have been shelved for lack of time or manpower at previous meetings and wrote M.Sc. or Ph.D. theses that were closely connected with one of the industrial problems. Let Tayler[15] indicate the benefits which accrued from the Study Groups.

> Companies that had spent some time discussing a research problem with a graduate student were anxious to employ him, and the students gained insight into what it might be like to work in an industrial environment. Indeed, many discovered that some of their preconceived ideas about the lack of challenge in industrial research were false, and the stimulation of a real, as opposed to an academic, problem had a marked effect on graduates who had followed mostly pure mathematics courses as undergraduates.
>
> Thus an unforeseen and valuable educational benefit was conferred, and the department graduate strength in applied mathematics increased. Also in this phase some companies were keen to send observers, possibly because of the opportunities for recruitment of graduates with some experience of and taste for industrial research, and the total number of industrial visitors increased substantially.

Conclusion

To conclude, we make the simple observation that sustained economic growth cannot be created by governmental edicts, by monetary policy or by tax cuts alone. Technological literacy of a high order is crucial to our future industrial competitiveness. The need to ensure that the moving frontier of facts is fed into professional practice has never been more urgent in our nation's history: the advancement of industrialisation requires the application of the most recent advances in science to technology. The costs to the nation, for ignoring or failing to meet the need to supply the market with men and women trained to exploit to the full the possibilities opened up by the technological revolution, will be high indeed. Unless there is an appropriate and immediate response from our higher education institutions, Australia's technological sovereignty and excellence would be gravely imperilled.

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